agriculture

MDPI

Editorial

Sustainability and Energy Economics in Agriculture

Štefan Bojnec [1,2]

[1] Department of Economics, Faculty of Management, University of Primorska, Izolska Vrata 2, SI-6000 Koper, Slovenia; stefan.bojnec@fm.upr.si or stefan.bojnec@siol.net
[2] Institute of Economic Policy and Finance, Faculty of Economics and Management, Slovak University of Agriculture in Nitra, Tr. A. Hlinku 2, 949 76 Nitra, Slovakia

Sustainable rural development rests on a careful balance between sustainable agriculture and the rural energy sector. The two can be mutually reinforcing, but they also involve trade-offs, for instance, when agriculture underpins food security while energy production competes for the same agricultural and forestry resources. Delivering food security and energy security, alongside a transition to clean energy, is not feasible without sustained investment and more efficient use of scarce rural resources. As demands for both food and energy rise, pressure on natural capital intensifies, as does the need to expand clean energy from solar, wind, geothermal, tidal and wave power, and from biomass and other bioresources, including agricultural outputs. Meeting these intertwined goals requires interdisciplinary solutions that integrate technological innovation with regulation, policy design, landscape and environmental planning, and socioeconomic and cultural considerations. The central challenge is to provide affordable, reliable energy without compromising food security, natural resources and environmental protection, or stakeholder consensus in rural areas. This Special Issue consists of empirical, methodological, and theoretical contributions that examine the links among agriculture and bioeconomy, rural areas, energy systems, and related socioeconomic activities.

Agriculture and rural areas sit at the centre of two interdependent transitions: ensuring resilient food production under tightening environmental constraints, and expanding access to affordable, reliable, and low-carbon energy [1]. Agriculture both depends on energy—through fertilisers, irrigation, mechanisation, processing, and logistics—and provides resources for energy production through biomass, residues, and land-based renewables [2]. These linkages create important synergies and spill-over effects but also expose trade-offs involving land and water competition, biodiversity impacts, greenhouse gas emissions, possible negative externalities for the environment and pollution, and social acceptance [3,4]. Understanding the sustainability implications of these interactions is therefore essential for designing pathways that protect natural capital while maintaining farm viability and rural livelihoods.

Energy economics provides the analytical tools to evaluate these choices by accounting for price volatility, investment risk, technology costs, and environmental externalities, as well as distributional impacts across regions and social groups [5]. Policies such as carbon pricing, renewable energy support, agri-environmental measures, and rural development programmes shape incentives for producers, households, and financial institutions, influencing the pace and inclusiveness of adoption [6,7]. At the same time, governance challenges—coordination across sectors, credible regulation and institutions, and transparent monitoring—determine whether innovations translate into measurable gains in efficiency and emissions reductions or negative externalities. A rural management perspective is thus needed to align farm-level decisions with broader climate, energy, and

Check for updates

Received: 28 April 2026
Accepted: 28 April 2026
Published: 30 April 2026

Copyright: © 2026 by the author. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license.

sustainability objectives. Among the special challenges are digital transformation in agriculture and AI-driven next-generation agriculture [8–10].

The Special Issue Sustainability and Energy Economics in Agriculture–2nd Edition (Section: Agricultural Economics, Policies and Rural Management) brings together empirical, methodological, and conceptual contributions that examine how energy transitions interact with agricultural production systems, bioeconomy strategies, environmental performance, and rural well-being. The papers span topics from bioenergy and household energy transitions to smart irrigation, digital agriculture, green finance and environmental, social, and governance (ESG) policy implementation, and market integration and sustainability indicators in Europe. The remainder of this article summarises the main insights from the included studies and concludes by outlining key implications for policy design, investment priorities, and cross-sector coordination in support of sustainable agriculture and rural development.

Sugarcane Biogas Production Pathways: Sugarcane biorefineries generate large volumes of residues such as vinasse and filter cake that can be converted into biogas/biomethane, creating an opportunity to diversify revenues while lowering lifecycle greenhouse gas emissions [11]. Whether these pathways are deployed at scale depends on their cost competitiveness relative to fossil alternatives and on the strength and volatility of decarbonisation incentives (e.g., carbon credits and fuel policy instruments) [12,13]. The sugarcane-based biogas production routes and how economic performance and policy design jointly shape investment decisions are relevant to the study [14], which offers a robust and timely assessment of the economic feasibility of biomethane production in sugarcane biorefineries by combining circular economy principles with stochastic price modelling. By applying Monte Carlo simulations, the study demonstrates that biomethane exhibits greater price stability and stronger linkage to fossil fuel markets than decarbonisation credits, supporting its role in long-term investment strategies. The results reveal that even under conservative assumptions, biomethane projects can achieve high internal rates of return and short payback periods. The analysis underscores the importance of policy frameworks such as RenovaBio and carbon pricing mechanisms in enhancing the economic viability of bioenergy pathways. The study provides valuable evidence for policymakers and industry stakeholders aiming to advance low-carbon energy transitions in agro-industrial systems.

Clean Energy Adoption in Rural Households: Clean energy adoption in rural households can act as a multidimensional development lever, reshaping not only energy access but also income opportunities, health, time use, and environmental conditions [15]. In China, where the rural energy transition is advancing alongside poverty alleviation and revitalisation policies, understanding how shifts from solid fuels to cleaner options translate into comprehensive welfare gains is increasingly important [16–18]. Evidence on the welfare impacts of clean energy uptake—and the distribution of those impacts across genders and regions—to inform more inclusive and effective policy design is improving over time, but new challenges are induced due to different factors. The global transition toward clean energy is increasingly recognised as a cornerstone of sustainable rural development and improved human well-being. Rural households remain at the centre of this transition, where energy choices directly influence economic conditions, health outcomes, environmental quality, and social equity. Recent empirical evidence demonstrates that adopting clean energy—particularly clean cooking fuels—can substantially enhance the comprehensive welfare of rural residents, while discontinuation leads to measurable welfare losses. Importantly, these benefits are not uniform but vary across genders and regions, highlighting the need for context-sensitive policy design [19]. The integration of behavioural economics with welfare analysis provides valuable insights into the complex

decision-making processes underlying household energy use. As countries pursue the Sustainable Development Goals, clean energy policies should move beyond infrastructure provision toward inclusive, evidence-based strategies that address affordability, accessibility, and social heterogeneity. Strengthening this nexus between energy transition and rural welfare is essential for achieving resilient, equitable, and sustainable agricultural systems.

Smart Irrigation Technologies: Climate-related water scarcity has become a substantial threat to agricultural and overall economic development in different parts of the world [20,21]. Irrigation can play an important role in agriculture [22,23]. However, irrigation is both a major driver of agricultural water withdrawals and a significant source of on-farm energy demand, making efficiency gains critical for climate resilience and cost control [24]. Energy-efficient smart irrigation technologies—combining sensors, automation, decision-support tools, and renewable-powered pumping—offer a practical route to cut water losses and electricity/fuel use while stabilising yields. These innovations can be translated into measurable water–energy savings, and adoption conditions can enable sustained benefits at the farm level. Water scarcity and energy inefficiency are among the most pressing constraints facing contemporary agriculture in developing countries, particularly in arid and semi-arid regions. The rapid diffusion of energy-efficient smart irrigation technologies offers a timely and practical pathway to address these intertwined challenges by improving resource efficiency while sustaining agricultural productivity [25]. Empirical evidence from water-stressed regions demonstrates that solar-powered smart irrigation systems can significantly enhance crop yields while substantially reducing both water and energy consumption [24]. In addition to productivity gains, these technologies can contribute to environmental sustainability by lowering greenhouse gas emissions and mitigating pressure on depleted water resources. Importantly, farmer experience and satisfaction emerge as critical determinants in realising the full benefits of smart irrigation adoption. The findings underscore the need for integrated policy frameworks that combine financial incentives, technical training, and renewable energy infrastructure development [24]. Advancing smart irrigation technologies is therefore essential for building resilient, climate-adaptive, and sustainable agricultural systems in developing countries.

Renewable Energy Consumption: In developed economies, expanding renewable energy is central to decarbonisation strategies, yet overall ecological footprints may remain elevated due to high income levels, consumption patterns, and production structures [26,27]. Renewable energy consumption can influence ecological footprint dynamics while accounting for the roles of financial development and agricultural activity [28]. Energy transitions and greener finance can be aligned with productivity in the agri-food sector to reduce environmental pressure. Reducing environmental pressure while sustaining economic activity remains a central challenge for modern agricultural and energy systems. Evidence from Denmark illustrates that increased renewable energy consumption plays a critical role in lowering the ecological footprint, even in highly developed and resource-efficient economies [28]. At the same time, continued expansion of agricultural, forestry, and fisheries activities, together with economic growth and financial development, can intensify environmental pressures if not carefully managed. These findings highlight the dual nature of development processes, where progress in production and finance should be aligned with sustainability objectives. Integrating renewable energy more deeply into agricultural systems offers a viable pathway to decouple growth from environmental degradation. Policymakers are therefore encouraged to complement renewable energy investments with targeted measures that promote low-emission farming practices and green finance. A coordinated approach across energy, agriculture, and economic policy is essential for achieving long-term environmental sustainability.

Green Business Model for Biofortified Foods: Strengthening food security while safeguarding natural resources remains a core challenge for agricultural development in many rural regions [29–31]. The contribution [32] highlights how green business models centred on biofortified foods can simultaneously address nutritional deficiencies, environmental degradation, and economic vulnerability among smallholder farmers. By integrating biofortification into a locally grounded and economically viable production and commercialisation strategy, the study demonstrates the potential to enhance access to nutrient-rich foods without exacerbating pressure on ecosystems. The proposed model illustrates how sustainable crop management, responsible input use, and short market chains can contribute to soil recovery, reduced environmental impacts, and improved rural livelihoods. Importantly, the analysis shows that regulatory compliance and nutritional safety are essential prerequisites for scaling biofortified food initiatives. The case of Chocontá underscores the importance of linking public policy, green finance, and farmer capacity-building to ensure successful adoption [32]. Such integrated approaches are crucial for advancing sustainable agriculture, promoting inclusive rural development, and improving long-term food and nutritional security.

Smart Agriculture and Technological Innovation: Smart agriculture is emerging as a key response to rising food demand, climate volatility, and increasing pressure on land, water, and energy resources. Enabled by digital transformation—through sensors, Internet of Things (IoT) connectivity, satellite and drone data, artificial intelligence, and decision-support systems—farms can monitor conditions in real time and apply inputs with greater precision [33–35]. These technologies promise higher productivity and resilience while reducing waste, greenhouse gas emissions, and other environmental impacts across the agri-food value chain. At the same time, the sustainability outcomes of digitalisation depend on inclusive adoption, data governance, and supportive policies that help small and medium-sized farms participate in innovation [36–39]. A study based on a systematic literature review considers how technological advances are reshaping agricultural practices and what is needed to ensure that smart agriculture contributes to sustainable and equitable rural development [40]. Technological progress is rapidly reshaping agriculture, positioning digital innovation as a central pillar for productivity, sustainability, and resilience in agri-food systems. This bibliometric analysis [40] provides a comprehensive overview of how research on smart agriculture has evolved over recent decades, revealing a sharp acceleration since 2020 driven by advances in artificial intelligence, precision agriculture, automation, and biotechnology. The findings highlight the increasingly interdisciplinary nature of this field, where technological innovation intersects with climate change mitigation, resource efficiency, and economic transformation. International collaboration networks show a strong concentration of research leadership in China, followed by the United States, Australia, and several European countries, underscoring the globalisation of agricultural innovation. At the same time, emerging economies are gradually strengthening their role through strategic research partnerships. The study [40] identifies important gaps related to the social, economic, and ethical implications of digitalisation, particularly for small and medium-sized farms. Addressing these challenges should require coordinated policies, transdisciplinary research, and inclusive innovation strategies to ensure that smart agriculture contributes to sustainable and equitable food systems.

Environmental, Social, and Governance (ESG) Policies: ESG policies are becoming a central feature of strategic management and regulatory compliance in the financial sector, shaping how institutions assess risk, allocate capital, and engage with communities [41–43]. However, the success of ESG frameworks depends not only on formal policies but also on how employees understand, interpret, and operationalise them in day-to-day work [44–47]. The specific study [48] examines employee perceptions of ESG policy implementation in

urban and rural financial institutions, focusing on differences in training, resources, leadership support, and internal communication. By comparing these contexts, it highlights organisational factors that facilitate or constrain consistent ESG practice and identifies where capacity-building is most needed to reduce implementation gaps. The effective implementation of ESG policies in financial institutions is a key driver of sustainable development, particularly in rural and agri-food contexts. The study [48] provides valuable insights into how employees perceive ESG practices in urban and rural banks, revealing clear disparities in engagement, training, and institutional support. Employees in urban banks report stronger involvement in ESG initiatives, more systematic training, and clearer governance structures, while their rural counterparts face notable limitations in resources, guidance, and internal coordination. These differences underline the critical role of organisational culture, infrastructure, and human capital in translating ESG strategies into everyday practice. Importantly, the findings highlight the underutilised potential of rural financial institutions to support sustainable agriculture and local development through targeted green finance instruments. Strengthening employee education, transparency, and internal communication in rural banks emerges as a priority for improving ESG outcomes. The study underscores that inclusive, employee-centred ESG implementation is essential for reducing urban–rural gaps and enhancing the contribution of financial institutions to sustainable agricultural and rural development.

Agri-Food Price Transmission and Price Integration: Pigmeat markets in Europe are strongly shaped by feed costs and purchasing power [49,50], yet price transmission is rarely confined to national borders in an integrated single market [51,52]. Because wheat is a major component of pig diets, changes in wheat prices can translate into shifts in production costs and, ultimately, pig carcass prices, while annual income influences demand conditions and consumers' willingness to pay. At the same time, geographic proximity and cross-border trade create spatial linkages through which shocks in one country can spill over into neighbouring markets. Price volatilities and price risk perception can be due to climate change and require food supply chain management strategies, particularly in niche pork markets [53–55]. Different methodological approaches have been applied to study these complex relationships. For example, the study [56] applies spatial panel regression to quantify both the direct effects of wheat prices and income and the extent of spatial dependence in pig carcass price formation across European countries. Price formation in the livestock sector reflects a complex interaction among input costs, consumer demand, and regional market integration. The study [56] provides empirical evidence that wheat prices, as a key feed input, and population income levels jointly shape pork carcass prices across European Union (EU) member states. By applying spatial panel econometric techniques, the authors demonstrate that price dynamics are not confined within national borders but are strongly influenced by developments in neighbouring markets, which is consistent with some previous studies [52]. The findings highlight the importance of spatial spillover effects, confirming the highly integrated nature of EU agricultural markets under the Common Agricultural Policy (CAP) framework. Income-driven demand heterogeneity further suggests that consumption patterns and price sensitivity differ substantially across regions. These results underline the need for coordinated information and cross-border monitoring of agricultural markets rather than isolated national interventions. The study [56] offers valuable insights for policymakers and stakeholders aiming to enhance market transparency, resilience, and efficiency in the European pigmeat sector.

Climate and Energy Agri-Environmental Indicators: Achieving the European Green Deal's objectives requires comparable and policy-relevant evidence on how agricultural systems contribute to climate mitigation and energy transition across the EU [57–59]. EU member states differ markedly in their production structures, resource endowments, and

technology uptake, which can translate into unequal performance in climate- and energy-related agri-environmental indicators [60–64]. The study [65] investigates these disparities by combining entropy-based indicator weighting with the PROMETHEE–GAIA multi-criteria decision framework to produce an integrated assessment and country ranking. By jointly examining greenhouse gas intensity and energy-use dimensions, the analysis identifies patterns of convergence and persistent heterogeneity that are critical for designing more differentiated and effective policy responses. The transition of European agriculture toward climate neutrality and energy efficiency remains uneven across EU member states, despite shared policy objectives under the CAP and the European Green Deal. The study [65] provides a data-driven assessment of climate- and energy-related agri-environmental indicators. The results reveal selective convergence in greenhouse gas emission intensity, indicating partial alignment of national agricultural systems with EU climate objectives. In contrast, energy-related indicators remain highly heterogeneous, reflecting persistent structural differences in energy efficiency, renewable integration, and agricultural productivity across countries. The ranking highlights that leading countries achieve balanced performance through lower emission intensity and more efficient energy use relative to agricultural value added, rather than exceptional performance in a single indicator. These findings stress that uniform policy targets are insufficient to address diverse national conditions. A differentiated, indicator-specific policy approach is therefore essential to ensure a more inclusive and effective climate and energy transition in European agriculture.

Household Biogas Adoption: Expanding access to clean and sustainable household energy remains a central challenge for rural development, environmental protection, and public health in low- and middle-income countries [66–69]. The study [70] provides policy-relevant evidence on the factors shaping household biogas adoption among dairy-farming households in West Java, Indonesia. The findings demonstrate that adoption is driven less by basic socioeconomic characteristics and more by perceived functional benefits, particularly time savings, fuel-cost pressure, and participation in training programs. Importantly, the results show that resource availability alone, such as livestock ownership, does not guarantee adoption, underscoring the importance of operational capability and institutional support. The negative association between higher formal education and adoption highlights the role of alternative energy preferences and suggests the need for targeted, context-specific promotion strategies. By combining empirical analysis with an interpretive adoption framework, the study bridges gaps between energy policy ambitions and household-level realities. The study offers valuable insights for designing biogas programs that are better aligned with users' daily practices, agricultural systems, and long-term sustainability goals.

Conclusion: This Special Issue underscores that sustainable rural development depends on integrated solutions at the agriculture–energy nexus that raise resource efficiency and accelerate decarbonisation without undermining food security, natural resources, or social acceptance. Across the contributions, economic viability and policy credibility and transparency emerge as decisive: sugarcane biorefineries can profitably valorise residues into biomethane, yet investment outcomes remain strongly shaped by carbon-pricing instruments and the stability of incentive schemes. At the household level, clean energy adoption delivers broad welfare gains (health, time use, and livelihoods), but impacts are heterogeneous across genders and regions, implying that affordability and accessibility measures must be tailored rather than uniform.

Technological change—smart irrigation, precision and AI-enabled farming, and decentralised renewables—offers concrete pathways to reduce water and energy use, emissions, and exposure to climate shocks, but benefits materialise only with enabling institutions,

skills, and finance. Evidence on ESG implementation further shows that organisational capacity and internal communication can widen or narrow urban–rural gaps in green finance delivery, while cross-border price spillovers in EU livestock markets and persistent heterogeneity in climate–energy agri-environmental performance highlight the need for coordinated monitoring and differentiated policy mixes. The papers converge on a common message: effective rural transitions require stable, well-designed incentives; inclusive adoption strategies; and cross-sector governance that coherently and transparently aligns energy policy, agricultural innovation, and sustainability objectives.

Conflicts of Interest: The author declares no conflicts of interest.

References

1. Chhabra, G.; Kaushik, K.; Chugh, P.; Dahiva, S.; Chaudhary, A. *Demystifying Sustainable Farming Using Smart Technologies*, 1st ed.; Apple Academic Press: New York, NY, USA, 2026.
2. Getahun, S.; Kefale, H.; Gelaye, Y. Application of precision agriculture technologies for sustainable crop production and environmental sustainability: A systematic review. *Sci. World J.* **2024**, *2024*, 2126734. [CrossRef] [PubMed]
3. Et-taibi, B.; Abid, M.R.; Boufounas, E.; Morchid, A.; Bourhnane, S.; Hamed, T.A.; Benhaddou, D. Enhancing water management in smart agriculture: A cloud and IoT-based smart irrigation system. *Results Eng.* **2024**, *22*, 102283. [CrossRef]
4. Wolfert, S.; Ge, L.; Verdouw, C.; Bogaardt, M.-J. Big data in smart farming—A review. *Agric. Syst.* **2017**, *153*, 69–80. [CrossRef]
5. Dodder, R.S.; Kaplan, P.O.; Elobeid, A.; Tokgoz, S.; Secchi, S.; Kurkalova, L.A. Impact of energy prices and cellulosic biomass supply on agriculture, energy, and the environment: An integrated modeling approach. *Energy Econ.* **2015**, *51*, 77–87. [CrossRef]
6. Baležentis, T.; Butkus, M.; Štreimikienė, D. Energy productivity and GHG emission in the European agriculture: The club convergence approach. *J. Environ. Manag.* **2023**, *342*, 118238. [CrossRef]
7. Polwaththa, K.; Amarasinghe, A.Y.; Nandasena, G. A review of innovative fertilization strategies in precision agriculture. *Open Access Res. J. Sci. Technol.* **2024**, *12*, 49–57. [CrossRef]
8. Symeonaki, E.; Maraveas, C.; Arvanitis, K.G. Recent advances in digital twins for agriculture 5.0: Applications and open issues in livestock production systems. *Appl. Sci.* **2024**, *14*, 686. [CrossRef]
9. Sun, Y.; Miao, Y.; Xie, Z.; Wu, R. Drivers and barriers to digital transformation in agriculture: An evolutionary game analysis based on the experience of China. *Agric. Syst.* **2024**, *221*, 104136. [CrossRef]
10. Nasar, M.; Kausar, M.A.; Nayyer, M.A. Towards next-generation agriculture: An AI-driven industry 5.0 model for IoT-enabled smart farming. *Next Res.* **2026**, *8*, 101526. [CrossRef]
11. Brando, C.M.; Stradiotto, N.R. Comparative Economic Analysis of the Utilization of Biogas from Sugarcane Vinasse in Electricity Generation, Transport Fuel and Natural Gas Substitution: A Brazilian case Study. *Waste Biomass Valorization* **2024**, *16*, 2497–2520. [CrossRef]
12. Klein, B.C.; Chagas, M.F.; Watanabe, M.D.B.; Bonomi, A.; Maciel Filho, R. Low carbon biofuels and the New Brazilian National Biofuel Policy (RenovaBio): A case study for sugarcane mills and integrated sugarcane-microalgae biorefineries. *Renew. Sustain. Energy Rev.* **2019**, *115*, 109365. [CrossRef]
13. Vandenberghe, L.P.S.; Valladares-Diestra, K.K.; Bittencourt, G.A.; Torres, L.Z.; Vieira, S.; Karp, S.G.; Sydney, E.B.; de Carvalho, J.C.; Soccol, V.T.; Soccol, C.R. Beyond sugar and ethanol: The future of sugarcane biorefineries in Brazil. *Renew. Sustain. Energy Rev.* **2022**, *167*, 112721. [CrossRef]
14. Fava, F.E.; Alves, L.R.A.; Romanelli, T.L. Economic Feasibility and Decarbonization Incentives of Sugarcane Biogas Production Pathways. *Agriculture* **2025**, *15*, 380. [CrossRef]
15. Clausen, L.T.; Rudolph, D. Renewable energy for sustainable rural development: Synergies and mismatches. *Energy Policy* **2020**, *138*, 111289. [CrossRef]
16. Li, L.; Fan, F.; Liu, X. Determinants of rural household clean energy adoption intention: Evidence from 72 typical villages in ecologically fragile regions of western China. *J. Clean. Prod.* **2022**, *347*, 131296. [CrossRef]
17. Zhu, H.; Ma, W.; Vatsa, P.; Zheng, H. Clean energy use and subjective and objective health outcomes in rural China. *Energy Policy* **2023**, *183*, 113797. [CrossRef]
18. Yin, S.; Fan, Y.; Gao, X. Transitioning to clean energy in rural China: The impact of environmental regulation and value perception on farmers' clean energy adoption. *J. Renew. Sustain. Energy* **2024**, *16*, 055904.
19. Qi, J.; Li, H.; Ye, F.; Zhang, L.; Yang, T.; Yan, C. Powering Rural Prosperity: How Clean Energy Adoption Transforms Comprehensive Welfare of Rural Residents in China. *Agriculture* **2025**, *15*, 392. [CrossRef]
20. Ingrao, C.; Strippoli, R.; Lagioia, G.; Huisingh, D. Water scarcity in agriculture: An overview of causes, impacts and approaches for reducing the risks. *Heliyon* **2023**, *9*, e18507. [CrossRef]

21. Filho, W.L.; Totin, E.; Franke, J.A.; Andrew, S.M.; Abubakar, I.R.; Azadi, H.; Nunn, P.D.; Ouweneel, B.; Williams, P.A.; Simpson, N.P. Understanding responses to climate-related water scarcity in Africa. *Sci. Total Environ.* **2022**, *806*, 150420. [CrossRef]
22. Kamran; Khan, J.A.; Safdar, F.; Khayyam, U.; Adil, I.H.; Waheed, A.; Khokhar, M.F. Drivers of Municipal Water Security and Vulnerability in Pakistan: A Case Study of Mardan, Khyber Pakhtunkhwa. *Groundw. Sustain. Dev.* **2024**, *26*, 101229. [CrossRef]
23. Nasreen, S.; Ashraf, M.A. Inadequate supply of water in agriculture sector of Pakistan due to depleting water reservoirs and redundant irrigation system. *Water Conserv. Manag.* **2020**, *5*, 13–19. [CrossRef]
24. Daraz, U.; Bojnec, Š.; Khan, Y. Energy-Efficient Smart Irrigation Technologies: A Pathway to Water and Energy Sustainability in Agriculture. *Agriculture* **2025**, *15*, 554. [CrossRef]
25. Bwambale, E.; Abagale, F.K.; Anornu, G.K. Smart irrigation monitoring and control strategies for improving water use efficiency in precision agriculture: A review. *Agric. Water Manag.* **2022**, *260*, 107324. [CrossRef]
26. Acaravci, A.; Ozturk, I. On the relationship between energy consumption, CO_2 emissions and economic growth in Europe. *Energy* **2010**, *35*, 5412–5420. [CrossRef]
27. Destek, M.A.; Sinha, A. Renewable, non-renewable energy consumption, economic growth, trade openness and EF: Evidence from organisation for economic Co-operation and development countries. *J. Clean. Prod.* **2020**, *242*, 118537. [CrossRef]
28. Dogan, M.; Georgescu, I.; Çeştepe, H.; Sarıgül, S.S.; Tatar, H.E. Renewable Energy Consumption and the Ecological Footprint in Denmark: Assessing the Influence of Financial Development and Agricultural Contribution. *Agriculture* **2025**, *15*, 835. [CrossRef]
29. Ansah, I.G.K.; Gardebroek, C.; Ihle, R. Resilience and household food security: A review of concepts, methodological approaches and empirical evidence. *Food Secur.* **2019**, *11*, 1187–1203. [CrossRef]
30. Bjornlund, V.; Bjornlund, H.; van Rooyen, A. Why food insecurity persists in sub-Saharan Africa: A review of existing evidence. *Food Secur.* **2022**, *14*, 845–864. [CrossRef]
31. Abebaw, S.E. A global review of the impacts of climate change and variability on agricultural productivity and farmers' adaptation strategies. *Food Sci. Nutr.* **2025**, *13*, e70260. [CrossRef]
32. Ortega-Ramírez, A.T.; Escobar Toro, L.F.; Reyes Tovar, M. Proposal for a Green Business Model for Biofortified Foods in the Municipality of Chocontá, Cundinamarca. *Agriculture* **2025**, *15*, 991. [CrossRef]
33. Basso, B.; Antle, J. Digital Agriculture to Design Sustainable Agricultural Systems. *Nat. Sustain.* **2020**, *3*, 254–256. [CrossRef]
34. Lavanya, G.; Rani, C.; Ganeshkumar, P. An automated low cost IoT based Fertilizer Intimation System for smart agriculture. *Sustain. Comput. Inform. Syst.* **2019**, *21*, 39–45.
35. El Bilali, H.; Strassner, C.; Ben Hassen, T. Sustainable Agri-Food Systems: Environment, Economy, Society, and Policy. *Sustainability* **2021**, *13*, 6260. [CrossRef]
36. Prasad, G.D.S.; Vanathi, A.; Devi, B.S.K. A Review on IoT Applications in Smart Agriculture. In *Recent Developments in Electronics and Communication Systems: Proceedings of the First International Conference on Recent Developments in Electronics and Communication Systems (RDECS-2022)*; SAGE Publications: Thousand Oaks, CA, USA, 2023; pp. 683–688.
37. Yang, C.; Ji, X.; Cheng, C.; Liao, S.; Obuobi, B.; Zhang, Y. Digital Economy Empowers Sustainable Agriculture: Implications for Farmers' Adoption of Ecological Agricultural Technologies. *Ecol. Indic.* **2024**, *159*, 111723. [CrossRef]
38. Narasimha Rao, G.B. Applications of Artificial Intelligence in Precision Agriculture to Ameliorate Production and Distribution. *Adv. Mod. Agric.* **2024**, *4*, 2374.
39. Duguma, A.L.; Bai, X. How the internet of things technology improves agricultural efficiency. *Artif. Intell. Rev.* **2025**, *58*, 63. [CrossRef]
40. Gherțescu, C.; Manta, A.G.; Bădîrcea, R.M. Smart Agriculture and Technological Innovation: A Bibliometric Perspective on Digital Transformation and Sustainability. *Agriculture* **2025**, *15*, 1388. [CrossRef]
41. Chen, P.; Yue, C. Construction of green finance's ESG evaluation system for rural innovation and entrepreneurship. *Int. J. Low-Carbon Technol.* **2024**, *19*, 2646–2655. [CrossRef]
42. Kwilinski, A.; Lyulyov, O.; Pimonenko, T. The role of green finance in attaining environmental sustainability within a country's ESG performance. *J. Innov. Knowl.* **2025**, *10*, 100674. [CrossRef]
43. Ye, X.; Tian, X. Green finance and ESG performance: A quasi-natural experiment on the influence of green financing pilot zones. *Res. Int. Bus. Financ.* **2025**, *73*, 102647. [CrossRef]
44. Aivaz, K.-A.; Misa, A.; Teodorescu, D. Exploring the role of education and professional development in implementing corporate social responsibility policies in the banking sector. *Sustainability* **2024**, *16*, 3421. [CrossRef]
45. Witt, N.; Thorsoe, M.H.; Graversgaard, M. ESG reporting meets farmer—Implications of the European corporate sustainability reporting directive for the agrifood sector. *Br. Food J.* **2025**, *127*, 264–283. [CrossRef]
46. Novellis, D.G.; Pedrazzoli, A.; Pennetta, D.; Venturelli, V. Greenwashing, greenhushing, and the path to green banking. *Glob. Financ. J.* **2025**, *67*, 101147. [CrossRef]
47. Zournatzidou, G. Green finance and sustainable development: Investigating the role of greentech business ecosystem through PRISMA-driven bibliometric analysis. *Adm. Sci.* **2025**, *15*, 150. [CrossRef]

48. Vapa Tankosić, J.; Lekić, N.; Čavlin, M.; Burnać, V.; Mirkov, M.; Prodanović, R.; Bejatović, G.; Prdić, N.; Mirjanić, B. Employee Perceptions of ESG Policy Implementation in Urban and Rural Financial Institutions. *Agriculture* **2025**, *15*, 1684. [CrossRef]
49. Pindyck, R.S. Volatility and commodity price dynamics. *J. Futures Mark.* **2004**, *24*, 1029–1047. [CrossRef]
50. Bojnec, Š.; Peter, G. Vertical Market Integration and Competition: The Meat Sector in Slovenia. *Agric. Food Sci.* **2005**, *14*, 236–249. [CrossRef]
51. Serra, T.; Gil, J.M. Local polynomial fitting and spatial price relationships: Price transmission in EU pork markets. *Eur. Rev. Agric. Econ.* **2006**, *33*, 415–436. [CrossRef]
52. Bakucs, Z.; Bojnec, Š.; Fertő, I. Spatial Product Market Integration between Two Small, Open Neighbouring Economies. *Agribusiness* **2015**, *31*, 171–187. [CrossRef]
53. Steen, M.; Berglad, O.; Gjolberg, O. Climate Change and Grain Price Volatility: Empirical Evidence for Corn and Wheat 1971–2019. *Commodities* **2023**, *2*, 1–12. [CrossRef]
54. Assefa, T.T.; Meuwissen, M.P.; Oude Lansink, A.G. Price risk perceptions and management strategies in selected European food supply chains: An exploratory approach. *NJAS Wagening. J. Life Sci.* **2018**, *80*, 15–26. [CrossRef]
55. Sónta, M.; Rekiel, A.; Wiecek, J.; Zalewska, A. Pig welfare and productivity in selected alternative systems. A niche market for pork. *Ann. Anim. Sci.* **2026**, *26*, 147–156.
56. Dinu, M.; Beia, S.I.; Pătărlăgeanu, S.R.; Gheorghe, A.F.; Munteanu, I.D.; Sacală, M.D. Exploring the Impact of Wheat Prices and Annual Income on Pig Carcass Prices in European Countries: A Spatial Panel Regression Analysis. *Agriculture* **2025**, *15*, 2216. [CrossRef]
57. Hasler, B.; Termansen, M.; Nielsen, H.O.; Daugbjerg, C.; Wunder, S.; Latacz-Lohmann, U. European agri-environmental policy: Evolution, effectiveness, and challenges. *Rev. Environ. Econ. Policy* **2022**, *16*, 105–120. [CrossRef]
58. Silvestri, C.; Silvestri, L.; Piccarozzi, M.; Ruggieri, A. Toward a framework for selecting indicators for measuring sustainability and circular economy in the agri-food sector: A systematic literature review. *Int. J. Life Cycle Assess.* **2024**, *29*, 1446–1484. [CrossRef]
59. Kowalska, A. A new measure of food system sustainability for use in European Union policy-making. *Sci. Total Environ.* **2025**, *1001*, 180326. [CrossRef]
60. Peng, B.; Melnikiene, R.; Balezentis, T.; Agnusdei, G.P. Structural dynamics and sustainability in the agricultural sector: The case of the European Union. *Agric. Food Econ.* **2024**, *12*, 31. [CrossRef]
61. Haller, A.P.; Dragolea, L.; Bruma, I.S. The dynamics of European agri-food sector and environmental challenges in Europe: An economic perspective. *Agric. Econ.* **2025**, *13*, 67. [CrossRef]
62. Bojnec, Š.; Fertő, I. Agri-environmental schemes reduce variable input costs: Evidence from Slovenian farms. *J. Clean. Prod.* **2026**, *554*, 148054. [CrossRef]
63. Bojnec, Š.; Fertő, I. Do agri-environmental schemes reduce farm greenhouse gas emissions? Evidence from Slovenia. *Sci. Total Environ.* **2026**, *1014*, 181387. [CrossRef] [PubMed]
64. Tsiaras, S.; Mantzoukas, S. PROMETHEE-Based Ranking of EU Countries Across Key Agricultural and Environmental Indicators. *Appl. Sci.* **2026**, *16*, 1131. [CrossRef]
65. Pantović, D.; Lojanica, N.; Bojnec, Š.; Gričar, S. Assessing Disparities in Climate and Energy Agri-Environmental Indicators Among EU Countries Using the PROMETHEE–GAIA Method and the Entropy Index. *Agriculture* **2026**, *16*, 463.
66. Budiman, I.; Muthahhari, R.; Kaynak, C.; Reichwein, F.; Zhang, W. Multiple Challenges and Opportunities for Biogas Dissemination in Indonesia. *Indones. J. Energy* **2018**, *1*, 46–60. [CrossRef]
67. Mukoro, V.; Sharmina, M.; Gallego-Schmid, A. A Review of Business Models for Access to Affordable and Clean Energy in Africa: Do They Deliver Social, Economic, and Environmental Value? *Energy Res. Soc. Sci.* **2022**, *88*, 102530. [CrossRef]
68. Tolessa, A. Current Status and Future Prospects of Small-Scale Household Biodigesters in Sub-Saharan Africa. *J. Energy* **2024**, *2024*, 5596028. [CrossRef]
69. Motevakel, P.; Roldán-Blay, C.; Roldán-Porta, C.; Escrivá-Escrivá, G.; Dasí-Crespo, D. Strategic Resource Planning for Sustainable Biogas Integration in Hybrid Renewable Energy Systems. *Appl. Sci.* **2025**, *15*, 642. [CrossRef]
70. Situmeang, R.; Mazancová, J.; Roubík, H. Policy-Relevant Insights into Household Biogas Adoption in West Java, Indonesia: Evidence from a Logistic Regression Analysis. *Agriculture* **2026**, *16*, 892. [CrossRef]

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.